

IDA PAPER P-3019

PROPOSED DEPARTMENT OF DEFENSE
SOFTWARE METRICS IMPLEMENTATION PLAN

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Prepared for
Office of the Director of Defense Research and Engineering

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Contract MDA 903 89 C 0003
Task T-A15-742

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PREFACE

This document was prepared by the Institute for Defense Analyses under the Task Order, Analysis of Software Initiatives, for the Office of the Director of Defense Research and Engineering. It fulfills an objective of the task, to prepare a software metrics implementation plan.

A review of this document was performed by Mr. Bill R. Brykczynski, Dr. Michael C. Frame, Ms. Audrey A. Hook, and Dr. Richard J. Ivanetich.

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EXECUTIVE SUMMARY

This report presents a proposed plan for Department of Defense (DoD) implementation of software metrics. The overall vision is to establish a department-wide, bottom-to-top corporate approach for collecting and using software metrics to improve analysis and decision-making in software acquisition and risk management. Acquisition reform and the long-standing need for effective risk management are anticipated drivers toward more specific metrics goals comparable to industry's goals of marketplace benefits from using software metrics. A significant theme is leveraging industry metrics practice, rather than creating unique military metrics definitions and standards, thereby minimizing the burden upon contractors. Another important theme is transmitting summary metrics and historical program data to the Office of the Secretary of Defense (OSD) to support department-wide analyses for improving acquisition methods and software risk management methods and tools. This would strengthen OSD leadership, and also contribute to the risk management capabilities of the Program Managers. It is not intended that OSD analysis would monitor or reassess current program management decisions.

The plan is framed as eight recommendations and a list of future research and development work that would support the plan's implementation. In summary, the purposes of the recommendations are respectively 1) collecting contractor-defined metrics on all Acquisition Category I and II programs, 2) evaluating contractors' software process capabilities for source selection and acquisition reviews, 3) independently evaluating software product risks prior to approval for engineering and manufacturing development, 4) using quantitative risk reduction metrics as part of milestone reviews, 5) reporting software metrics to OSD through the established acquisition summary reports, 6) establishing a software improvement analysis activity at OSD using contractor resources, 7) archiving program metrics and other software data to support historical improvement studies as part of the OSD analysis effort, and 8) providing visibility to research and development supporting DoD-wide metrics implementation.

INSTITUTE FOR DEFENSE ANALYSES

**PROPOSED DEPARTMENT OF DEFENSE
SOFTWARE METRICS IMPLEMENTATION PLAN**

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PHASE 2 OBJECTIVE & SCOPE

This report documents Phase 2 of a one-year task to assess software metrics and to determine how the Department of Defense (DoD) could improve its use in software acquisition, particularly of weapon system software. The report responds to task order requirements to the Institute for Defense Analyses (IDA) from the Office of the Director, Defense Research and Engineering (ODDR&E), summarized in this chart. The plan is framed as eight recommendations. The first six recommendations relate to the first two bullets under Scope. (Phase 1 results [Springst 1994] primarily identified beneficial capabilities, first bullet.) Recommendation 7 addresses the use of a DoD-wide repository (third bullet). Recommendation 8 and a table of recommended research and development work in support of this plan comprise suggestions for future Science and Technology (S&T) plans (fourth bullet under Scope).

PHASE 2 OBJECTIVE & SCOPE

OBJECTIVE:

- **Develop a software metrics implementation plan for DDR&E**

SCOPE:

- **Identify metrics capabilities of most benefit to DoD acquisition process**
- **Identify process to implement best metrics practices in weapon system software acquisition**
- **Define process for using a DoD-wide metrics data repository**
- **Identify new metrics technologies for DoD software S&T program**

DRIVERS

This chart lists the main drivers of the IDA recommendations. Their sources are identified in brackets [] following the phrase defining each driver. The drivers do not necessarily map exclusively to one or more recommendations. For example, an important driver is the current initiative toward acquisition reform articulated in Secretary Perry's policy memorandum, "Specifications and Standards—A New Way of Doing Business," dated 29 June 1994. This initiative has served as a guide for the plan's details, and more broadly, has influenced IDA to impose no added burden on contractors in the plan.

In developing this plan, IDA interviewed some of the staff of the Under Secretary of Defense, Acquisition and Technology (USD(A&T)). Their suggestions reinforced the importance of guidance for sound software risk management, e.g., [Carr 1993; Donis 1993, 1994; Fife 1993], and implied that insufficient software expertise is available for thorough reviews by the Defense Acquisition Board (DAB).

The importance of management commitment for success in implementing and using metrics was stressed during IDA's Phase 1 survey and a Software Round Table meeting that discussed the survey. (The Round Table is an informal interchange group of DoD software and measurement leaders that coincidentally commenced its activity at about the time IDA completed Phase 1. Its initial meeting provided insight on goals for advancing DoD's use of software metrics. It was evident that a successful metrics program requires senior-level commitment to push the use of quantitative measures into practice. Without senior commitment there is a strong propensity for Program Managers (PMs) to eliminate metrics due to the perceived added expense and the difficulties associated with collecting and understanding the measures. Senior managers can contribute significantly to the evolution of metrics use by supporting training for acquisition personnel along with continuing technical support for them to implement metrics effectively in their programs.

DRIVERS

- **DoD ACQUISITION REFORM GOALS [SecDef Policy Memo, 29 June 1994]**
 - Leverage industry's commercial efforts
 - Reduce constraints & intrusion on contractors
- **RISK MANAGEMENT [USD(A&T) staff interviews, DoD risk management guidance]**
 - Past inattention to contractors' software process capabilities
 - Concern for sound risk management and thorough DAB review
- **NEED FOR MANAGEMENT COMMITMENT [Phase 1 survey, DoD Software Round Table]**
 - Need for a DoD-wide vision for evolution & use of metrics
 - Propensity to eliminate metrics requirements from contracts
 - Lack of training, technical support, and funding for metrics collection and use

VISION AND THEMES

The overall vision of this plan is that DoD would establish a department-wide, bottom-to-top corporate approach for collecting and using software metrics to improve analysis and decision-making for software acquisition and risk management. Accomplishing this goal is beyond DDR&E's authority as principal advisor to USD(A&T) on scientific and technical matters, research, and weapon system development.* Much of the responsibility to achieve this would fall on Service program managers. Advocacy and technical support through DDR&E would be major contributions and vital within the weapon system domain. Acquisition reform and improving software risk management should provide specific goals to drive this vision, comparable to industry's goals of gaining marketplace advantages from software metrics.

To limit the scope for initiating this plan, it should be focused on the more costly acquisition programs, i.e., those in Acquisition Categories (ACAT) I and II. However, the purposes involved apply equally well to other categories, and in time, extending this vision to all DoD programs should be considered.

As already mentioned, a significant theme is to leverage industry metrics practice, rather than create new measurement definitions and standards unique to DoD, and thereby limit or minimize burden upon DoD contractors. Another important theme is to transfer summary metrics and historical program data to OSD to support DoD-wide analyses for improving acquisition methods and criteria, and software risk management methods and tools. This would strengthen OSD leadership, but also should improve risk management capabilities of the Program Managers. It is not intended, however, that such analysis would monitor or reassess current program management decisions.

*DoD Directive 5134.3, *Director of Defense Research and Engineering*, 9 January 1989.

VISION AND THEMES

Establish a DoD-wide approach for collecting and exploiting software metrics

- **Advocate through DDR&E technical authority and support**
- **Support DoD acquisition reform and risk management goals relative to software**
- **Direct with goals comparable to industry's corporate commitment and agenda**
- **Focus on ACAT I, II programs**
- **Revise regulations to accept contractor's metrics and commercial standards**
- **Provide data and analysis to strengthen OSD leadership**
- **Improve Program Managers' risk management capabilities**

SUMMARY OF PLAN'S RECOMMENDATIONS BY ORGANIZATIONAL LEVEL

This chart lists the eight recommendations that are the framework of the implementation plan. It also identifies two organizational levels associated with each. The Performing Organization is the one ultimately responsible to carry out the recommendation. The Using Organizations are the expected consumers of the results produced in performing each recommendation.

Later charts will elaborate the purpose, rationale, and criteria for each recommendation. The following are very brief comments to accompany this chart. Recommendations 1 through 5 are formulated to ensure that fundamental or "core" types of metrics are obtained on ACAT I and II programs, primarily for the Program Manager's benefit in risk management. A key criterion is that DoD accept the specific metrics that contractors already use for their management effort, with preference for typical industry standards of practice.

Recommendations 6 and 7 address the establishment of a software analysis and improvement group to provide OSD software expertise, to archive software metrics, and to improve the software acquisition process. USD(A&T) would oversee this effort since it focuses on improving the software acquisition process, but presumably would delegate operating responsibility to a staff official, e.g., to DDR&E. Program Managers should benefit directly from the improvement results.

Recommendation 8 proposes that DDR&E take action to focus research effort to better support the advancement of software measurement for risk management in acquisition programs. This recommendation would directly affect the architects of the DoD S&T Plan.

SUMMARY OF PLAN'S RECOMMENDATIONS BY ORGANIZATIONAL LEVEL

Recommendation	Performing Organization	Using Organizations
1. Obtain contractors' software metrics for all ACAT I & II programs	Program Manager	Program Manager
2. Evaluate contractors' software processes for acquisition decisions	Program Manager	Program Manager, USD(A&T) Staff, and DAB
3. Conduct independent software product risk assessment for milestone 2 review	Program Manager	Program Manager and DAB
4. Assess technical risk reduction and set future goals at milestone reviews	Program Manager	Program Manager and DAB
5. Report basic software metrics and risks to aid DoD-wide improvement analyses	Program Manager	Program Manager, DoD software improvement activity
6. Establish a DoD software improvement analysis activity at OSD	As delegated by USD(A&T), e.g., DDR&E	Program Manager and OSD Staff
7. Retain software experience data for long-term improvement analyses	As delegated by USD(A&T), e.g., DDR&E	Program Manager, DoD software improvement activity
8. Provide focus for research supporting DoD-wide metrics use in risk management	DDR&E	Research planners

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ALTERNATIVE IMPLEMENTATION STRATEGIES

There are two alternative ways for proceeding to implement this plan. One is to direct fulfillment of the acquisition and program management requirements through revisions of the Defense supplement to Federal Acquisition Regulations (DFARS) and DoD Instruction 5000.2 and other pertinent guidance. This is the recommended approach, for several reasons. It would indicate commitment at the highest DoD management levels to metrics use as a valuable element of acquisition reform and technical improvement analyses. It would ensure the availability of metrics data for all of the relatively few ACAT I and II programs, not just programs in the weapon system domain or those that would voluntarily comply. It also appears timely just now to take this approach as DFARS and DoDI 5000.2 changes are being formulated to implement acquisition reform and "best software acquisition practices," a recent joint initiative of USD(A&T) and the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (ASD(C3I)).

If such a compliance approach is not taken, an alternative strategy would be to set up incentives for acquisition program managers and OSD staff to undertake these recommendations voluntarily. Current DFARS and DoDI 5000.2 do not prevent DoD components, program offices, and the DAB from following the recommendations in a manner appropriate to each organization. Some current programs are performing one or more of the recommendations, and experience and guidance are available to help others.

An incentives strategy applying just to the weapon system domain could begin from a DoD Metrics Vision and Strategy document that would provide DDR&E's advocacy and guidance to Service acquisition managers and staff. This document should describe concrete examples of goals and benefits, operating concepts, and illustrative implementations, and also identify sources of support and training as well as additional incentives, if any, such as supplemental funding. This document is envisioned as "how to" and motivating guidance rather than a fixed plan of required actions.

ALTERNATIVE IMPLEMENTATION STRATEGIES

Recommendation	Compliance Strategy	Incentives Strategy
1. Obtain contractors' software metrics for all ACAT I & II programs	Direct by DFARS and DoDI 5000.2 revisions	Advocate in a DoD Metrics Vision & Strategy document
2. Evaluate contractors' software processes for acquisition decisions	Direct by DFARS and DoDI 5000.2 revisions	Advocate in a DoD Metrics Vision & Strategy document
3. Conduct independent software product risk assessment for milestone 2 review	Direct by DFARS and DoDI 5000.2 revisions	Advocate in a DoD Metrics Vision & Strategy document
4. Assess technical risk reduction and set future goals at milestone reviews	Direct by revised DAB review guidance	Advocate in a DoD Metrics Vision & Strategy document
5. Report basic software metrics and risks to aid DoD-wide improvement analyses	Direct by revised DAES reporting criteria	Advocate in a DoD Metrics Vision & Strategy document
6. Establish a DoD software improvement analysis activity at OSD	Authorize by charter and operating plan	OSD offices fund individual analyses as their goals require
7. Retain software experience data for long-term improvement analyses	Authorize by charter and operating plan	Advocate as Service responsibility in a DoD Metrics Vision & Strategy document
8. Provide focus for research supporting DoD-wide metrics use in risk management	Direct by S&T plan guidance	Adopt focus desired by S&T planners

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SUMMARY OF PLAN'S RECOMMENDATIONS AND PERTINENT BEST PRACTICES

This chart maps the recommendations to Best Industry Practices to illustrate that the latter have been recognized and how they can be applied DoD-wide. These Best Practices were identified during the Phase I survey. They include collecting simple software measurements, placing a focus on continuous improvement, establishing the necessary guidance and support structure, as well as identifying appropriate research projects to support these practices.

Industry experience shows that a small set of basic measures and collection practices works best, especially in starting a corporate-wide metrics initiative. Successful metrics programs emphasize improvement progress within each project, rather than use of metrics to compare projects to one another for effectiveness judgements. The best measurement programs establish a focus group to provide guidance and support in several areas, including training, tools, and analysis. Best Practice indicates that appropriate guidance is necessary for establishing uniform practices across a group and for facilitating communication within a group. The industry community surveyed in Phase 1 also stressed the need for continued software measurement research to address emerging technical issues and technology transfer problems, such as the lack of highly effective metrics tools, appropriate metrics relative to different software development methodologies, and decision aids to analyze measurement data relative to potential risk mitigation or improvement actions.

The DoD can leverage from these Best Practices by (1) collecting and archiving contractor-defined software metrics, using independent evaluations of contractors' software processes and products as part of risk management effort, (2) improving OSD access to measurements through the Defense Acquisition Executive Summary (DAES) reports and the DAB reviews, and (3) by stressing process improvement within DoD programs. These recommendations will be described in more detail in the following charts.

SUMMARY OF PLAN'S RECOMMENDATIONS AND PERTINENT BEST PRACTICES

Recommendation	Pertinent Best Industry Practice
1. Obtain contractors' software metrics for all ACAT I & II programs	Metrics collected expeditiously for each project, in best effort to meet corporate standards
2. Evaluate contractors' software processes for acquisition decisions	Proven review methods and criteria used to measure & improve company software practices
3. Conduct independent software product risk assessment for milestone 2 review	Risks reviewed by independent technical peers
4. Assess technical risk reduction and set future goals at milestone reviews	Metrics used to track improvement progress for each project or program
5. Report basic software metrics and risks to aid DoD-wide improvement analyses	Summary metrics reported for use in multi-project or domain improvement analyses
6. Establish DoD software improvement analysis activity at OSD	Central technical support provided for implementing and analyzing metrics within a business area or application domain
7. Retain software experience data for long-term improvement analyses	Historical data used to gauge improvement progress and to formulate corporate objectives
8. Provide focus for research supporting DoD-wide metrics use in risk management	Pilot projects and other improvement research identified in business improvement plans

SCHEME FOR DETAILING EACH RECOMMENDATION OF THE PLAN

Each of the recommendations is described in a standard format consisting of six categories: What, Why, Who, How, When, and Cost.

What and *Why* describe each recommendation in terms of its substance and the motivation behind it. *Who* describes those who ultimately must implement the recommendation, while *How* identifies who has the authority to direct the implementation, along with the DoD regulations that would require modification. Resource requirements are broken down into schedule and cost constraints. *When*, i.e., the schedule, accounts for time necessary to draft the implementation requirements and a subsequent grace period for DoD organizations to put them into effect. *Cost* accounts for an acquisition program's expenses to implement the recommendation. It does not include the cost of staff or working groups that develop the implementation guidance unless it appears that this would be a substantial effort.

As mentioned earlier, the specific schedule and other criteria given in Secretary Perry's June 29 policy memorandum have been used as a guide here for the actions proposed on DFARS, DoDI 5000.2, and Request for Proposal (RFP) requirements. Further, the same schedule has been advanced as an approximation for most of the recommendations, rather than estimating minor schedule distinctions for implementing each one.

Although Recommendations 1 through 7 each identify a working group to develop specific implementation guidance, all of this effort could be done effectively by a single group.

SCHEME FOR DETAILING EACH RECOMMENDATION OF THE PLAN

WHAT

What is the substance of the recommendation and its intended result?

WHY

What is the motivation for and benefit of the recommendation?

WHO

Who is affected and ultimately responsible to fulfill the recommendation?

HOW

Who can require compliance and how is it directed?

How are specific implementation criteria to be developed?

WHEN

How long before compliance should be achievable, and how long to develop the specific implementation language, in calendar months?

COST

Estimate the cost of implementing the recommendation for an individual acquisition program. Also indicate cost for defining the implementation requirements if this might exceed a few staff labor months.

1. OBTAIN CONTRACTORS' SOFTWARE METRICS FOR ALL ACAT I & II PROGRAMS

Given the Phase 1 evidence that industry typically collects and uses metrics for its own management and improvement purposes, it is recommended that a core set of those software metrics be requested of each software contractor on a regular reporting interval. The desired core metrics measure software activity cost, effort, schedule, size, requirements stability, and defects. The contractor's definition of available metrics and reporting interval should be accepted, although RFPs should indicate a competitive evaluation consideration for completeness and consistency with industry standards. This recommendation is not intended to reduce all program metrics to a common denominator, but rather to ensure low-cost availability of metrics as a foundation for software risk management efforts. Extant programs that already obtain such core metrics and others by different criteria would not have to modify or recompute contracts.

The high-level guidelines in the current DoDI 5000.2^{*} are too vague to achieve the purpose stated here, and specific RFP guidance and DFARS revisions will be needed. In addition, the work breakdown structure (MIL-STD-881), as revised or converted to an industry standard, will have to provide for accurately collecting all software effort and cost data.

Since the recommendation accepts pre-existing contractor-defined metrics, contractor expense is minimized. It is anticipated that it will take three months or less to draft the RFP guidance and other DoDI 5000.2 or DFARS revisions. Existing Service requirements that meet or exceed the intent here should be recognized rather than contradicted by any new guidance. Following USD(A&T) approval of the relevant new acquisition guidance, it is recommended that DoD organizations have an additional three months time to incorporate this into their acquisition directives to Program Managers.

^{*}Part 6, Section D, Attachment I

1. OBTAIN CONTRACTORS' SOFTWARE METRICS FOR ALL ACAT I & II PROGRAMS

WHAT

Require RFPs to solicit contractors' defined metrics on software cost, effort, schedule, size, requirements stability, and defects for all software work under acquisition category (ACAT) I & II programs

WHY

1. Ensure metrics are reported for DoD program and risk management
2. Minimize cost by accepting contractor's metrics over special DoD standards

WHO

Program managers to implement in solicitations per their organization's acquisition directives

HOW

1. USD(A&T) to authorize a working group to draft DFARS, DoDI 5000.2 revisions, and related criteria for work breakdown structure (MIL-STD-881 revision/conversion)
2. Guidance to recognize extant Service metrics policies and contracts
3. USD(A&T) to issue policy and DFARS, DoDI 5000.2 updates

WHEN

Estimate 3 months to develop guidance, then 3 months to implement

COST

Minimal cost expected, by accepting contractor-defined metrics

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2. EVALUATE CONTRACTORS' SOFTWARE PROCESSES FOR ACQUISITION DECISIONS

As part of source selection and milestone reviews of ACAT I & II programs, it is recommended that an independent evaluation be performed of all software contractors' development processes. During source selection, the evaluation will assess the risks associated with a bidding contractor's existing development practices. Once a contract is awarded, process evaluations will provide risk assessment and mitigation information as part of the milestone 1-3 reviews for 1) approval to proceed into Demonstration/Validation (Dem/Val), 2) approval for Engineering & Manufacturing Development (EMD), and 3) approval for Production. No single evaluation method is endorsed, although the same method should be used throughout a given program. Considerable experience exists already in DoD with alternative evaluation methods (e.g., Software Capability Evaluations (SCEs), Software Development Capability Reviews (SDC/CRs)). Industry standards are emerging for such methods, e.g., the International Organization for Standardization (ISO) efforts such as ISO 9000-3 and ISO Software Process Improvement Capability Evaluation (SPICE) projects.

Funding and accomplishing process evaluations is a PM responsibility, especially because PM guidance is needed to make the results most effective. To provide a check that the PM's source is indeed independent and technically qualified to produce a thorough evaluation, the pertinent USD(A&T) staff officer should concur in the evaluation team selection. To implement contractor evaluations for acquisition decisions, the Program Manager must include the requirements in the RFP and incorporate the results into source selection criteria and as contract requirements to support milestone reviews. The Appendix of this plan has an example of RFP requirements. USD(A&T) should authorize the development of common RFP guidance and necessary revisions to DoDI 5000.2 and DFARS.

From recent experience, it is estimated to cost approximately \$35K to \$100K to conduct an evaluation of one contractor's process, depending on the team source, size, and the complexity of program requirements.

2. EVALUATE CONTRACTORS' SOFTWARE PROCESSES FOR ACQUISITION DECISIONS

WHAT

Require independent evaluation of contractors' software development **processes** as part of competitive selection and milestone 1-3 reviews for ACAT I, II programs

WHY

Select lower-risk contractors who are applying metrics in organization-wide process improvement, and reinforce Service initiatives already paying off, e.g., SCEs required in Army Software Testing and Evaluation Panel (STEP) metrics and SDC/CR required for Air Force software-intensive systems

WHO

Source Selection Authority or Program Manager to select & fund independent team with concurrence of cognizant USD(A&T) staff officer

HOW

1. USD(A&T) to authorize a working group to draft recommended RFP guidance and DFARS, DoDI 5000.2 revisions, giving option on applicable commercial standard (e.g., ISO SPICE, ISO 9000-3)
2. USD(A&T) then issues policy and DFARS, DoDI 5000.2 updates

WHEN

Estimate 3 months to develop guidance, then 3 months to implement

COST

Estimate \$35K to \$100K per evaluation

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3. CONDUCT INDEPENDENT SOFTWARE PRODUCT RISK ASSESSMENT FOR MILESTONE 2 REVIEW

It is also recommended that all ACAT I & II programs undergo an independent product assessment prior to EMD, i.e., an evaluation addressing technical requirements and all achieved results such as software prototypes, design specifications, simulations or benchmarks, incremental software builds, and software test plans. This is recommended as most useful prior to milestone 2, given that many software products typically are produced in DEM/VAL, but less effective at other milestones either for lack of software products or because other formal test requirements begin to occur that accomplish a similar goal. The purpose of this assessment is to identify software product risks that may exist and to give the program manager and DAB reviewers an objective view of the achieved software quality.

To implement a product risk assessment, a program manager must inform the contractor of this review in the RFP. The assessment team also must be selected by the program manager, with concurrence of the cognizant USD(A&T) staff officer to ensure objectivity. Common RFP guidance and necessary revisions to DoDI 5000.2 and DFARS to implement the product assessments and their use within the DAB review process should be developed by a DoD working group. No specific product assessment method needs to be mandated, as several methods exist in the public domain, including risk checklists; e.g., [Carr 1993; Donis 1993, 1994; Fife 1993].

Because of the technical complexity anticipated for a typical number of engineering products, it is estimated to cost approximately \$300K to conduct such a product risk assessment.

3. CONDUCT INDEPENDENT SOFTWARE PRODUCT RISK ASSESSMENT FOR MILESTONE 2 REVIEW

WHAT

Conduct independent technical team assessment of software **product** risks prior to milestone 2 review for ACAT I, II programs

WHY

1. Obtain objective assessment for tracking with PM/contractor assessments
2. Augment DAB staff analysis and software expertise

WHO

Program managers to select & fund independent technical team with concurrence of cognizant USD(A&T) staff officer

HOW

1. USD(A&T) to authorize a working group or PAT to draft recommended RFP guidance and necessary DFARS, DoDI 5000.2 updates
2. USD(A&T) then issues policy & guidance on DAB requirements
3. Assessment team follows available methods & checklists, e.g., SEI or IDA, and reports to cognizant USD(A&T) Director after PM review

WHEN

Estimate 3 months to develop guidance, then 3 months to implement

COST

Estimate up to \$300K per assessment

4. ASSESS TECHNICAL RISK REDUCTION AND SET FUTURE GOALS AT MILESTONE REVIEWS

It is recommended that software development progress be measured, prior to milestone 1 through 3 reviews, against pre-defined quantitative goals related to software technical and performance risks. Currently, it is believed that insufficient software prototyping limits Program Office insight into contractor risk mitigation progress. The Acquisition Program Baseline (APB), which contains key performance, schedule, and cost parameters, usually does not allocate system performance requirements to measurable software performance requirements. Since software risks are not directly identified in the APB, OSD and the DAB have insufficient insight as well. Lack of visibility means software technical risks are not identified and resolved early in the system life cycle, where rework costs would be lower.

To ensure software technical risks are adequately addressed during the prototyping phases of development, Program Managers should specify measurable software performance requirements and set anticipated targets for each development phase. The results of software process evaluations (Recommendation 2) and the software product risk assessments (Recommendation 3) can be used to establish and verify these measurable goals. Reviews at milestones 1 through 3 should also evaluate the progress made to reduce existing software technical risks and establish measurable goals for satisfying future review criteria.

USD(A&T) guidance would be needed to incorporate software risk reduction measures into the DAB process. It is estimated to take approximately six months to draft, publish, and implement the appropriate guidance. The expected cost of implementing this within DoD programs should be minimal since it is an expected part of good system engineering practice. It will help to reduce life cycle cost by identifying and resolving risks early, and improving the thoroughness of DAB reviews.

4. ASSESS TECHNICAL RISK REDUCTION AND SET FUTURE GOALS AT MILESTONE REVIEWS

WHAT

Assess measurable software risk reduction progress at milestone 1-3 reviews. Measure progress by metrics and system performance criteria established at the prior milestone, and set anticipated reduction targets for the next phase.

WHY

USD(A&T) staff believe that prototyping often doesn't address software technical risks. System performance requirements often are not allocated to measurable software performance requirements in the APB.

WHO

1. Program managers specify software performance requirements
2. DAB review defines next milestone risk reduction metrics and targets

HOW

1. USD(A&T) to authorize a working group to draft recommended guidance for implementation in DAB activities
2. USD(A&T) then issues DAB review guidance to implement this effort

WHEN

Estimate 3 months to develop guidance, then 3 months to implement

COST

Minimal, expected from DoDI 5000.2 and good system engineering practice

5. REPORT BASIC SOFTWARE METRICS and RISKS TO AID DoD-WIDE IMPROVEMENT ANALYSES

In addition to incorporating measurable software risks into milestone reviews (Recommendation 4), it is recommended that these measures and the core metrics (Recommendation 1) should be incorporated into the quarterly DAES reports. The DAES report measures program performance against significant intermediate objectives as well as against key parameters identified in the APB. The guidance listed in 5000.2 (Part 16, Attachment C) includes a broad range of mission performance criteria that encompass software. But in practice, software-intensive ACAT I & II programs seldom report software-related data in the DAES reports. This limits OSD's understanding of risks and capability to assess problem sources in current acquisition practice or potential improvements. There is no mechanism now for capturing software data to identify risks that reoccur across the DoD or to focus DoD software process improvement efforts. Specially funded studies or PAT efforts are limited by lack of data or high cost of obtaining it from program office archives.

To improve the tracking and mitigation of software risks, it is necessary for Program Managers to capture and report basic software metrics and risk data. The USD(A&T) should establish a working group to develop improved software reporting criteria based on the set of measures identified in Recommendations 1 and 4. The group should also determine a means to capture the results of the software process and product evaluations (Recommendations 2 and 3). The results of the working group should be codified in appropriate revisions to 5000.2 to help ensure compliance DoD-wide.

It is estimated to take approximately six months to draft and implement new DAES reporting guidance. Implementing additional DAES reporting criteria into DoD programs is a minimal additional expense since it would report contractor-defined software measurements or data already produced from implementing other recommendations here.

5. REPORT BASIC SOFTWARE METRICS AND RISKS TO AID DoD-WIDE IMPROVEMENT ANALYSES

WHAT

Revise DAES reporting requirements for Phases 2-3 of the acquisition life cycle to include basic software metrics and risk assessments for all ACAT I, II programs

WHY

1. The DAES purpose is to report program status and performance issues including software—but in practice, software is not reported adequately
2. DoD-wide improvement analyses require basic data

WHO

Program managers to report metrics and risk data from contractors and other pertinent sources

HOW

USD(A&T) to authorize a working group to develop improved software reporting criteria as constrained by other recommendations herein

WHEN

Estimate 3 months to develop guidance, then 3 months to implement

COST

Minimal if programs have basic metrics available, e.g., per Recommendations 1 and 4

6. ESTABLISH A DoD SOFTWARE IMPROVEMENT ANALYSIS ACTIVITY AT OSD

It is recommended that an OSD analysis activity should be established to support software metrics implementation from a technical and operational standpoint, and to support OSD staff in software acquisition and risk management improvement efforts. Currently, the DAB is said to lack sufficient software data and expert resources to adequately review and monitor ACAT I & II programs. Industry Best Practice experience indicates that dedicated technical support is required to effectively implement a software measurement and process improvement program. This OSD analysis activity is not intended to require new DoD personnel slots or organizational structure. For example, the effort could be conducted through a Service acquisition office with primarily contractor resources.

The intended scope of the analysis effort includes evaluating the DoD software acquisition process, lessons learned, and risk mitigation strategies that could be applied DoD-wide. The effort would assist dissemination of Best Practices across DoD but would not develop new technology or development methodologies. It is not intended to monitor an individual program's performance or shortcomings. The Appendix contains a list of example projects that are considered in and out of scope. The analysis activity could well support the software executive council proposed by the Defense Science Board [DSB 1994] and the Software Acquisition Best Practices initiative of ASD(C3I) and USD(A&T).

To establish this software improvement analysis activity at OSD, USD(A&T) should authorize a working group to draft a charter for the activity and then delegate operating responsibility to a staff official, e.g., DDR&E. It is estimated to take approximately six months to draft the charter and first-year operating plan of the improvement analysis activity. It is envisioned that approximately four full-time staff years of labor would suffice for initial analyses. Once the reporting channel (Recommendation 5) is working and data becomes available, the amount of effort would increase for more thorough analyses.

6. ESTABLISH A DoD SOFTWARE IMPROVEMENT ANALYSIS ACTIVITY AT OSD

WHAT	Establish technical resources supporting the DAB and USD(A&T) staff in using metrics for software risk and acquisition improvement analyses
WHY	<ol style="list-style-type: none">1. USD(A&T) staff say that available software expertise often is insufficient2. Industry experience shows that technical support is needed for successful organization-wide improvement
WHO	USD(A&T) to authorize and delegate lead responsibility based on a plan
HOW	<ol style="list-style-type: none">1. USD(A&T) to authorize a working group to draft a charter, first-year operating plan, and budget. Scope to cover quick-reaction studies, consulting, historical analyses. Consider multiple contractors for resources.2. Consider affiliation with the DSB-proposed executive council and with the ASD(C3I) and USD(A&T) joint initiative on Software Acquisition Best Practices
WHEN	Estimate 6 months to develop proposed charter and first-year plan
COST	Estimate initial effort about 4 staff years per year, increasing as significant program data accrues

7. RETAIN SOFTWARE EXPERIENCE DATA FOR LONG-TERM IMPROVEMENT ANALYSES

Many ideas for innovation and technical improvement in software acquisition cannot be evaluated without sound historical records from a good sample of past programs. One current example would be developing and validating a software cost and schedule estimation model that accounts for recent trends toward increased use of commercial off-the-shelf (COTS) software and object-oriented (OO) design and analysis. Present management operations do not capture sufficient software data or conveniently archive it for historical analyses.

This recommendation proposes development and operation of an OSD archive or repository of software data from DAES reports, DAB reviews, and other program activities, to be accomplished as part of the improvement analysis activity described in the prior recommendation. This is envisioned as a modest effort for DoD purposes only. It does not seem critical to require a computer-based repository since limited effort would be better invested in consistency and completeness checking of available data and annotating it with program history to ensure its correct future interpretation. Acquisition programs providing the data should be given data service from the archive to help their comparative assessments and planning. A public data service is not recommended for lack of experience showing its possible value.

7. RETAIN SOFTWARE EXPERIENCE DATA FOR LONG-TERM IMPROVEMENT ANALYSES

WHAT

Evolve an archive or repository of software metrics and project data to aid long-term analyses of improvement opportunities

WHY

1. Available software project records are incomplete or obsolete
2. Historical and current data are needed to improve acquisition analysis models, e.g., independent software cost models of the CAIG
3. Program office planning could benefit from DoD-wide experience data

WHO

USD(A&T) to authorize and delegate lead responsibility based on plan below

HOW

1. Combine with the improvement analysis support and plan both together
2. Limit data service initially to supporting OSD studies or DoD contributors

WHEN

Coincides with planning to implement Recommendation 6, i.e., 6 months

COST

Estimate initial level of effort of one staff year per year for archiving DAES and other data, e.g., DAB materials & findings, for long-term use

TECHNOLOGY INTERESTS FROM PHASE I SURVEY AND SUBSEQUENT INTERVIEWS

This chart exhibits background information, preparatory to the next chart, which identifies recommended subjects for future S&T plans that would support this metrics implementation plan.

Interviews during and subsequent to the Phase 1 survey indicated certain metrics technology areas as worthy of further research and development, as listed in the left column of this table. However, this input was limited and did not provide substantive definition of concrete objectives. Some interest or need was expressed by the different types of organizations listed in the other three columns, denoted by a check mark for each area of interest.

In Phase 2, IDA investigated sources, e.g., Program Objectives Memorandum materials, that could provide insight into current S&T metrics efforts and needs. It was not possible to gain a complete picture of current objectives since metrics work usually was included as a secondary subject within a broader application-oriented topic, e.g., information science, but was not elaborated. It is believed that a significant part of current S&T metrics investment is in maintenance efforts, e.g., work to use such acquisition data as is available to gain insight on valid uses or limitations of existing cost estimation models.

TECHNOLOGY INTERESTS FROM PHASE I SURVEY AND SUBSEQUENT INTERVIEWS

Technology Area	Expression of Interest or Need		
	DoD Organizations in Phase 1 Survey	Companies in Phase 1 Survey	Software Round Table
Core metrics definition	✓	✓	✓
Metrics tools	✓	✓	
Performance measures	✓		
Decision aids	✓	✓	✓
OO metrics	✓	✓	
Cost estimation models	✓		
CMM metrics	✓		✓
Legacy records	✓	✓	
Metrics validation	✓		

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TECHNICAL NEEDS RELATED TO THE METRICS PLAN

The same technology areas identified in Phase 1 and subsequent interviews have been used here to categorize specific S&T objectives that would serve implementation of this plan. The chart provides a basic statement of each objective, and in the third column, an indication that the envisioned effort primarily involves either research, collection and interpretation of experience data, or a practical specification of requirements for an evident approach.

The stated objectives are considered self-explanatory for purposes of this plan. They support the plan's recommendations as follows:

1. Core metrics definition: Objective 1, Recommendation 1. Objective 2 provides an overall perspective for all DoD participants of the goals, benefits, and operational effect of this plan when implemented.
2. Metrics tools and CMM metrics: Recommendation 2
3. Performance measures: Recommendation 3
4. Decision aids: Recommendations 1 through 4
5. OO metrics: Recommendation 1
6. Cost estimation models: Recommendation 4
7. Legacy records: Recommendations 5 through 7
8. Metrics validation: Recommendations 1 through 4

TECHNICAL NEEDS RELATED TO THE METRICS PLAN

Technology Area	Specific Needs	Type of Effort
Core metrics definition	1. Common guidance for contractors to define their metrics for DoD use, for reference in future RFPs— industry standards to serve as base, e.g., IEEE Standard 1045-1992 2. DoD vision for metrics and their use in acquisition risk management	Practical formulation
Metrics tools	Guidance on basic tool capabilities needed for effective metrics implementation, related to key development goals and practices	Practical formulation
Performance measures	Guidance on selection and use of product performance measures in acquisition risk management	Experience analysis
Decision aids	Guidance and case studies for metrics-based software risk management	Research
OO metrics	Definition of core metrics for risk management with OO methodologies	Research
Cost estimation models	Improved estimation models accounting for ongoing technical paradigm shifts, e.g., OO methods, increasing use of COTS components, IDLs	Research
CMM metrics	Guidance on effective metrics capabilities related to key goals and practices of capability assessment models such as SEI's CMM	Practical formulation
Legacy records	Guidance for acquisition, organization, and archiving of project data and metrics for future analytical use	Experience analysis
Metrics validation	See decision aids above	N/A

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8. PROVIDE FOCUS FOR RESEARCH SUPPORTING DoD-WIDE METRICS USE IN RISK MANAGEMENT

Current S&T effort in software metrics lacks visibility and its overall purpose and effect are not evident. Metrics research and development should take on greater importance in view of current emphasis on acquisition reform and the need for better results despite funding cutbacks. It is recommended that DoD-wide metrics implementation become a visible category for describing and guiding future DoD S&T efforts. Other ideas for emphasizing the role and importance of metrics for software risk management should be considered within the scope of DDR&E authority. This chart lists a few possibilities, including the idea of identifying and funding DoD centers of excellence in software measurement and risk management. This was recommended also by the Software Round Table. Funding of pilot projects within the scope of selected major acquisition programs also should be considered, and is an example of a funding incentive that could prove effective in lieu of a compliance approach to implementing this plan.

8. PROVIDE FOCUS FOR RESEARCH SUPPORTING DoD-WIDE METRICS USE IN RISK MANAGEMENT

WHAT

1. Clearly identify goals and projects in S&T plans that will further DoD-wide acceptance and exploitation of metrics for acquisition risk management
2. Consider means to foster DoD-wide advocacy and authority, e.g., official roles, centers of excellence, or pilot projects within selected acquisition programs

WHY

Current metrics research has little visibility or implementation focus and may lack funding, but is not fundamentally unaware of relevant technology topics

WHO

S&T planners, following DDR&E guidance

HOW

1. Develop goal-oriented subjects within S&T plans
2. Use working groups to explore concrete means and projects
3. Consider coordination with current ASD(C3I) and USD(A&T) task force on best software acquisition practices

WHEN

Estimate 3 months to frame guidance for next S&T planning cycle

COST

Minimal for planning effort, associated research costs not estimated

SUGGESTED FIRST STEPS TOWARD IMPLEMENTATION

The current acquisition reform activity to revise DoDI 5000.2 and the DFARS may be addressing similar issues as this plan, so it will be important to examine the proposals from that activity for coordination or revision of this plan.

Added insight on potential implementation constraints and opportunities could come from USD(A&T) staff or others at OSD, so briefings to them about these proposals could prove very helpful for refining this plan.

The key decision not yet fully resolved is whether a compliance approach through DoDI 5000.2 and DFARS should be undertaken or else use an incentives approach. This plan recommends the compliance approach as both opportune and offering greater support of acquisition reform and improved risk management. But, as the Software Round Table suggested, an incentives approach would be a valuable contribution to advance the use of metrics.

The Appendix provides limited examples concerning the instruments to implement this plan, e.g., RFP guidance, improvement analysis operating plan. If a compliance approach is decided, further drafting work on such instruments should help gain USD(A&T) approval to proceed further. If an incentives approach is chosen, then work on the DoD Software Metrics Vision and Strategy is recommended, along the lines indicated in describing ALTERNATIVE IMPLEMENTATION STRATEGIES on page 10.

SUGGESTED FIRST STEPS TOWARD IMPLEMENTATION

- **Assess effect on this report, i.e., Recommendations 1 through 4, of imminent USD(A&T) proposed language (DFARS, DODI 5000.2) for implementing acquisition reform**
- **Brief this report to selected USD(A&T) staff**
- **Resolve the implementation choice of compliance through DoDI 5000.2 and DFARS revisions, or an incentives approach**
- **Draft RFP guidance (Recommendations 1-3), analysis service charter (Recommendation 6), and DoD vision for metrics (see slide on page 10) as starting points**

APPENDIX

RFP REQUIREMENTS FOR CONTRACTOR SOFTWARE PROCESS EVALUATION

To require software process evaluations of contractors for source selection and milestone reviews, the Program Office (PO) must develop the guidance and detailed requirements incumbent on offerors and contractors, as appropriate. This guidance will identify the process evaluation method and criteria to be used (e.g., SCE, SDC/CR, ISO) and describe the procedures and support pertinent to conducting the evaluations. This chart suggests appropriate partial text for the RFP's Statement of Work, Instructions for Proposal Preparation, and Evaluation Criteria, assuming that all necessary guidance and detailed requirements are provided in one manual, here called the Process Evaluation Guide. Refer to [Springst 1992] for additional examples and details pertinent to the use of SEI's maturity model.

RFP REQUIREMENTS FOR CONTRACTOR SOFTWARE PROCESS EVALUATION

Statement of Work (Section C of RFP)

"Every offeror and after award, every contractor or subcontractor that performs software effort, shall provide personnel, resources, and facilities to support a series of independent evaluations of the contractor's software development organization and process. Each evaluation will be performed by an external, government-designated team of software experts for up to five consecutive days. Evaluations will be scheduled during the proposal evaluation period and within three months of each Defense Acquisition Board program milestone review scheduled during the contract term. The evaluation team shall use (reference to Process Evaluation Guide) to determine the strengths and weaknesses of the contractor's software development process. The contractor's process will be evaluated in each of the areas for (insert any constraint on scope) as defined in the (reference to Process Evaluation Guide). The evaluation shall be based on the contractor's software development processes as documented in the Software Development Plan, Process Improvement Plan, and by prior accomplishments. The offeror or, as appropriate, contractors shall provide the personnel effort, resources, and support identified in (reference to Process Evaluation Guide) for each evaluation."

Instructions for Proposal Preparation (Section L of RFP)

"The offeror shall submit with their proposal the information requested in (reference to Process Evaluation Guide) to assist the Government's preparation of the software process evaluation during the proposal evaluation period."

Evaluation Criteria (Section M of RFP)

"The source selection criteria identified in (reference to Process Evaluation Guide) divide software considerations into several sections, one of which includes the results of the software process evaluation. It identifies how the evaluation results will be summarized in terms of red, yellow, green, and blue categories. The evaluation results will also identify the offeror's strengths and weaknesses in key areas as listed in (reference to Process Evaluation Guide)."

EXAMPLES OF SCOPE INTENDED FOR OSD SOFTWARE IMPROVEMENT ANALYSES

This chart provides further information about the intended scope of the OSD software improvement analysis activity. It lists examples of efforts that fall within the intended scope, and some examples of efforts that are not envisioned.

EXAMPLES OF SCOPE INTENDED FOR OSD SOFTWARE IMPROVEMENT ANALYSES

Examples within the intended scope of effort

- Assess the correlation of DEM/VAL prototyping investment and requirements stability in early EMD for avionics software
- Investigate risk-reducing benefits of early commitments to COTS software components
- Assess lessons learned in risk mitigation through software performance management
- Develop risk mitigation decision guidance based on effort and schedule trends prior to Critical Design Review
- Brief OSD staff on new metrics technology used in a program coming up for DAB review
- Assist ASD(C3I) staff to review benefits and limits of a given program's OO metrics

Examples outside the intended scope of effort

- Provide monthly assessments to OSD of a given program's status and risks
- Assess new interface protocols for distributed simulations
- Conceive and prototype new on-line metrics collection tools
- Devise a new software architecture methodology to reduce risk
- Assess the current maturity of OO database technology

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ACRONYMS

ACAT	Acquisition Category
APB	Acquisition Program Baseline
ASD(C3I)	Assistant Secretary of Defense for Command, Control, Communications, and Intelligence
CMM	Capability Maturity Model
COTS	Commercial off-the-shelf
DAB	Defense Acquisition Board
DAES	Defense Acquisition Executive Summary
DDR&E	Director of Defense Research and Engineering
DEM/VAL	Demonstration/Validation
DFARS	Defense [supplement to] Federal Acquisition Regulations
DoD	Department of Defense
DoDI	Department of Defense Instruction
EMD	Engineering Manufacturing and Development
IDA	Institute for Defense Analyses
IDL	Interface (or interconnection) Definition Language
IEEE	Institute of Electrical and Electronic Engineers
ISO	International Organization for Standardization

N/A	Not Applicable
OO	object-oriented (analysis, design, or programming)
OSD	Office of the Secretary of Defense
PAT	Process Action Team
PM	Program Manager
RFP	Request for Proposal
S&T	Science and Technology
SCE	Software Capability Evaluation
SDC/CR	Software Development Capability/Capacity Review
SecDef	Secretary of Defense
SEI	Software Engineering Institute
SPICE	Software Process Improvement Capability Evaluation
STEP	Software Testing and Evaluation Panel (of U. S. Army)
USD(A&T)	Under Secretary of Defense, Acquisition and Technology

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